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Pressure and temperature measurements with a dual-luminophor coating
- Carroll, B.F. Hubner, J.P. Schanze, K. Bedlek, J. Morris, M.
Dept. of Aerosp. Eng., Mech. & Eng. Sci., Florida Univ., Gainesville, FL, USA
This paper appears in: Instrumentation in Aerospace Simulation Facilities, 1999
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14-17 June 1999

Toulouse, France
1999

ISBN: 0-7803-5715-9

IEEE Catalog Number: 99CH37025

Number of Pages: viii+416

References Cited: 5

INSPEC Accession Number: 6597246

Abstract:

Data reduction requirements for dual-luminophor pressure/temperature sensitive (P/TSP) are explored through the use of principal component analysis. The dual-luminophor coating contains one luminophor which primarily responds to temperature and one which responds to both temperature and pressure. The analysis indicates that a two-factor reduced order model based on two fundamental spectral interaction effects between the luminophors. The inclusion of a third factor appears to sufficiently model the mutual interaction effects. This work indicates P/TSP data reduction procedures based on principal component analysis are promising for improving the accuracy of the measurements. The potential to remove the requirement for a wind-off reference image and to reject high frequency noise is also indicated.

Index Terms:

wind tunnels aircraft testing principal component analysis data reduction temperature measurement pressure measurement radiation quenching pressure sensors temperature sensors photoluminescence dual-luminophor coating temperature measurement data reduction requirements pressure/temperature sensitive pain component analysis two-factor reduced order model luminescence response mutual interaction effects measurement accuracy high frequency noise rejection oxygen quenching wind tunnel testing

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An optical technique for detecting fatigue cracks in aerospace structures

- [Banaszak, D. Dale, G.A. Watkins, A.N. Jordan, J.D.](#)

Air Vehicles Directorate, Wright-Patterson AFB, OH, USA

This paper appears in: Instrumentation in Aerospace Simulation Facilities, 1999

99. 18th International Congress on

On page(s): 27/1 - 27/7

14-17 June 1999

Toulouse, France

1999

ISBN: 0-7803-5715-9

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Number of Pages: viii+416

References Cited: 11

INSPEC Accession Number: 6597255

Abstract:

The development of a field-deployable non-intrusive optical-based crack-detect measurement system based on temperature-sensitive-paint (TSP) technology is described. The TSP developed is based on a platinum porphyrin immobilized in sol-gel-derived thin film. For this test, the TSP is deposited on top of an aluminum plate that is then subjected to dynamic fatigue through the use of an electrodynamic shaker. Detection of cracks in the aluminum is accomplished by monitoring the change in surface temperature of the plate as it was excited at its resonant frequency. Visualization and measurement of the cracks is easily accomplished in near real time using this method. Finally, this method is compared with conventional thermography, and results indicate that for aluminum, the surface-temperature change was below the resolution of conventional instrumentation.

Index Terms:

[crack detection](#) [infrared imaging](#) [fatigue cracks](#) [aerospace testing](#) [aerospace structures](#) [fatigue crack detection](#) [optical technique](#) [field-deployable](#) [temperature-sensitive paint](#) [platinum porphyrin](#) [sol-gel film](#) [immobilized](#) [dynamic fatigue](#)

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Application of temperature sensitive paint for detection of boundary layer transition - Popernack, T.G. Owens, L.R. Hamner, M.P. Morris, M.J.
Editor(s): Owen, F.K.

NASA Langley Res. Center, Hampton, VA, USA

This paper appears in: Instrumentation in Aerospace Simulation Facilities, 1997 '97 Record., International Congress on

On page(s): 77 - 83

29 Sept.-2 Oct. 1997

Pacific Grove, CA, USA

1997

ISBN: 0-7803-4167-8

IEEE Catalog Number: 97CH36121

Number of Pages: ix+470

References Cited: 6

INSPEC Accession Number: 5808995

Abstract:

Temperature sensitive paint systems exploit the variation in convective heat transfer associated with changes from laminar to turbulent flow for detection of boundary layer transition. For this detection technique, it is important for wind tunnel models to have a slow thermal response relative to convection heat transfer. Wind tunnels that can create rapid changes in freestream temperature can create a model thermal response that provides acceptable estimates to indicate transition. Numerical heat transfer simulations provide acceptable estimates to assess test techniques and model thermal characteristics. Data are presented to substantiate that the desired test condition could be achieved over a period of time sufficient to document the boundary layer state.

Index Terms:

boundary layers wind tunnels forced convection laminar to turbulent transitions flow aerodynamics temperature sensitive paint boundary layer transition convective heat transfer wind tunnel models thermal response freestream temperature heat transfer simulations test techniques boundary layer state

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TEMPERATURE SENSITIVE PAINT

High resolution, non-intrusive measurement temperature and heat transfer using temperature sensitive paint have been demonstrated by L. Campbell. A typical TSP consists of the luminescent molecule and an oxygen impermeable binder. The basis of the temperature sensitive paint method is the sensitivity of the luminescent molecules to the thermal environment. The luminescent molecule is placed in an excited state by absorption of a photon. The excited molecule deactivates through the emission of a photon. A rise in temperature causes the luminescent molecule to increase the probability that the molecule will return to the ground state through a radiationless process. This process is known as thermal quenching and is the basis of temperature sensitive paint. The temperature of the paint surface can be measured by detecting the fluorescence intensity $I(T)$ of the luminescent molecule.

The luminescent intensity of the temperature sensitive paint at a given point is not only a function of temperature. For practical applications of TSP, spatial variations in illumination, paint concentration, paint layer thickness, and camera sensitivity result in a variation in the detected luminescent intensity from the test surface. These spatial variations are eliminated by ratioing the luminescent intensity of the paint at the unknown test condition (I_T) with the luminescent intensity of the paint at a known reference condition (I_{ref} , T_{ref}).

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Fundamentals of Pressure and Temperature Sensitive Paints

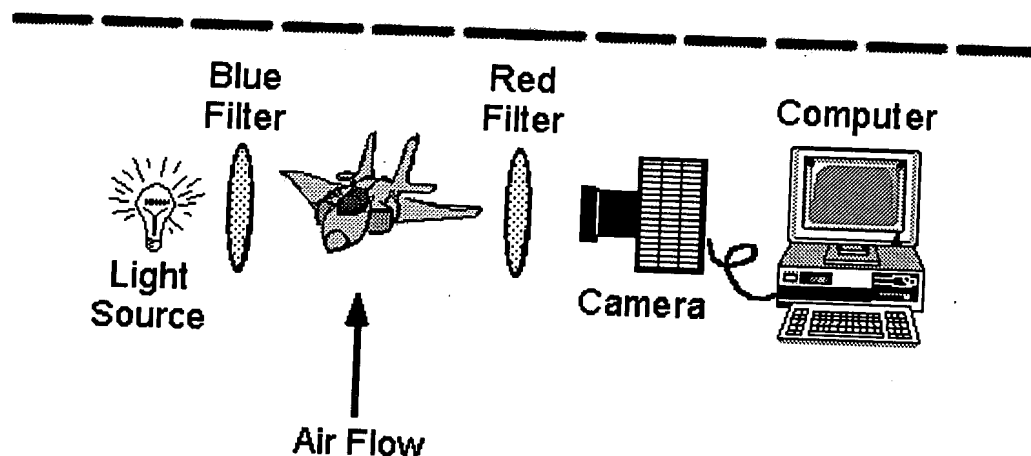


Figure 1. Typical Pressure or Temperature Sensitive Paint (PSP or TSP) experimental arrangement

Pressure and Temperature Sensitive Paints (PSP & TSP) are luminescent surface coatings for which the luminescence intensity is related to the surface pressure and temperature. PSP consists of an oxygen permeable polymer binder in which a luminescent dye is dispersed. The dye is excited by absorbing light (generally UV or blue) and relaxes by emitting red shifted light. An alternate decay process is through the interaction of the dye with an oxygen molecule (called oxygen quenching). As the pressure above the layer increases, the oxygen concentration within the layer will increase and the luminescence intensity will decrease.

The luminescence intensity of the dyes is also temperature dependent, as is the mass diffusivity of the polymer binder. These two effects cause PSP coatings to also be sensitive to temperature. To make a temperature sensitive paint (TSP), you simply disperse the dye in an oxygen impermeable binder such as epoxy. Dual purpose coatings for simultaneous pressure and temperature measurements are possible and are currently being developed by our group.

Figure 1 shows a typical experimental arrangement for either PSP or TSP. An illumination source is used to excite the paint layer coated on the model (in this case and aircraft in a wind tunnel). Common illumination sources are filtered tungsten-halogen lamps (450 nm) or the blue line of an argon-ion laser (488 nm). The red shifted luminescence is then measured with a camera/filter (600-650 nm) arrangement. The camera can be either a film based camera or a cooled CCD camera. For land based applications, the cooled CCD is generally more accurate and easier to use, while flight testing applications often require the film based method.

A schematic of the actual PSP layer is shown in Figure 2 for isothermal, steady state conditions. Temperature variations across the surface will introduce errors into the measurements. Additionally, unsteady pressures introduce problems since the oxygen concentration across the layer is no longer uniform due to finite diffusion times. A TSP layer would be similar except that the binder would be oxygen impermeable such that the oxygen concentration within the layer would be zero.

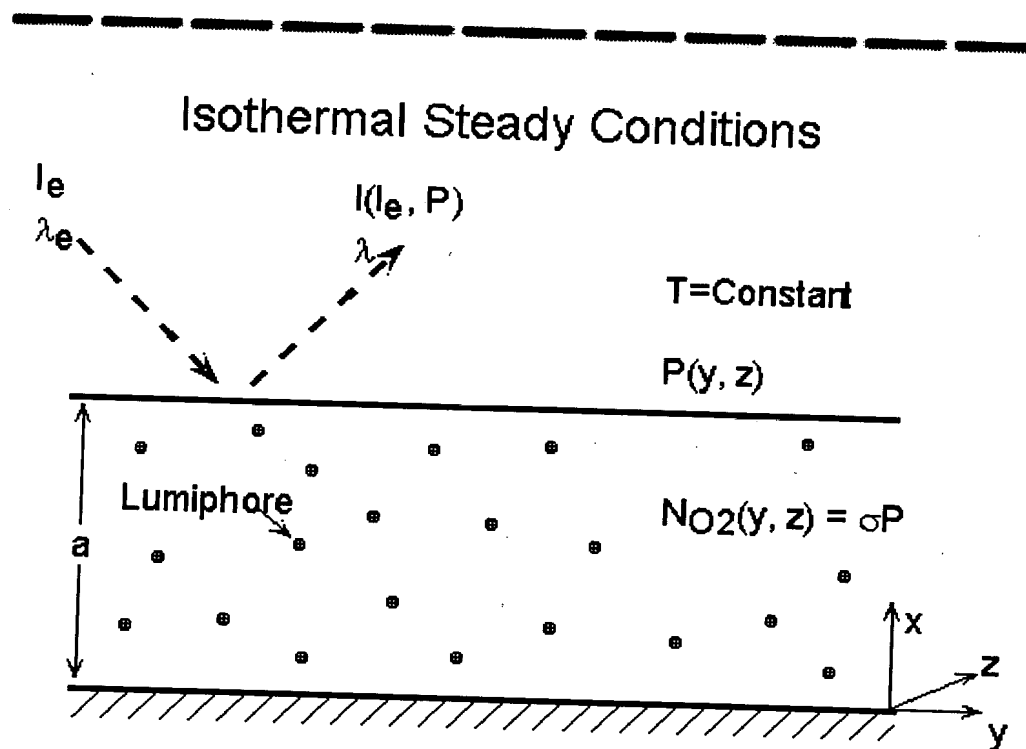
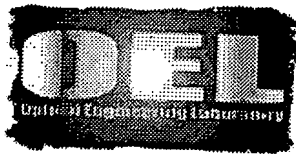


Figure 2. Enlargement of a PSP coating. The layer is held at constant temperature and pressure

Opportunities for Graduate Study

Contact Dr. Carroll (bfc@aero.ufl.edu) if you are interested in research areas described in this web site. Graduate assistantships and scholarships are available for qualified applicants.

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In recent years, new techniques based on luminescence quenching have been developed for measuring temperature distributions on wind tunnel models. New sensors are called temperature-sensitive paint (TSP). By comparison with conventional techniques such as thermocouples and pressure taps, the TSP techniques provide a way to obtain simple, inexpensive, full-field measurements of temperature with much higher spatial resolution. TSP incorporates luminescent molecules in a paint which can be applied to any aerodynamic model surface. Figure 1 shows a schematic of a paint layer incorporating luminescent molecules.

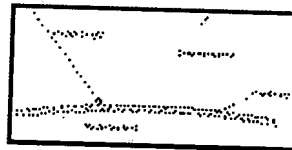


Figure 1: Schematic of TSP/PSP Layer

The paint layer is composed of luminescent molecules and a polymer binding material which can be dissolved in a solvent. The resulting paint can be applied to a surface using a brush or sprayer. As the paint dries, the solvent evaporates, leaving behind a polymer matrix with luminescent molecules embedded in it. When the proper wavelength of light is directed at the model, the luminescent molecules are excited and emit light of a longer wavelength. Using the proper filters, the excitation light and luminescent emission light can be separated and the intensity of the luminescent light determined using a photodetector. Through the photo-physical processes of thermal- and oxygen-quenching, the luminescent intensity of the paint is related to temperature. Hence, from the detected luminescent intensity, the temperature can be determined. Figure 2 shows a typical surface temperature map for supersonic flow around a cylinder with a turbulent boundary layer.

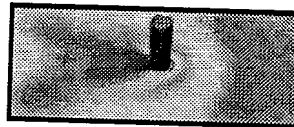


Figure 2 Surface temperature map for supersonic flow around a cylinder with a turbulent boundary layer at Mach = 2.5.

These TSP techniques have been under development at Purdue University.

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Questions about the OEL and related courses should be directed to Professor Peter Bryanston-Cross

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Paints contain 4 basic ingredients, pigment, binder, solvent, and additives. Pigments give the paint color and hiding ability, and some provide stain blocking and corrosion resistance. Titanium Dioxide is the most commonly used hiding pigment. Clays, talc, and other materials are used as extender pigments. The binder is the resin that holds the dried paint together. Typical resins are acrylic, vinyl acrylic, alkyd, urethane, and epoxy. The binder is what usually determines the resistance characteristics of the paint, including such things as scrubbability, fade resistance, flexibility, etc. The binder also helps the paint adhere to a surface. Solvents are used to disperse or dissolve the solids in the paint and allow it to be applied to a surface. They affect application characteristics, dry time, and, in two component materials, the rate of chemical reaction between the two parts. Additives are used to improve such things as mildew resistance, thickness, in-can stability, and stain blocking ability to name a few.